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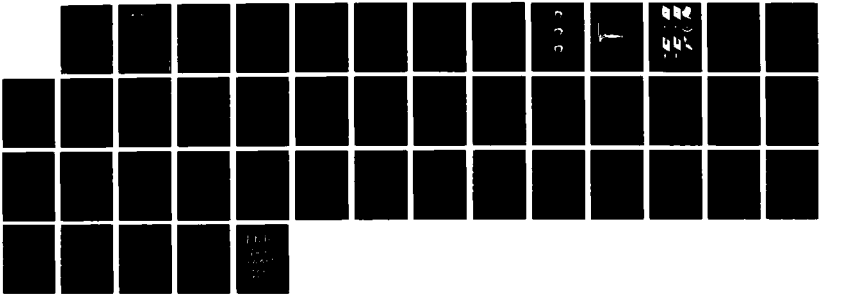

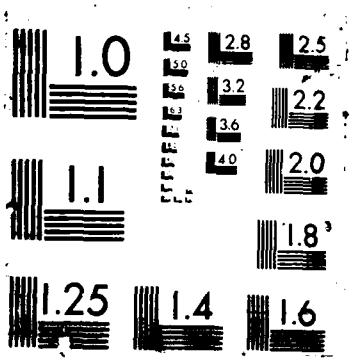
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A team of eleven Ph.D. scientists and several graduate students has been assembled at USU to work in close collaboration with scientists at the Air Force Geophysics Laboratory on a number of problems that are relevant to Air Force systems, including OTH radars, communications, and orbiting space structures. The overall goal of the research is to obtain a better understanding of the basic chemical and physical processes operating in the geoplasma environment, including the ionosphere, thermosphere, and magnetosphere. Some of the specific tasks include the following: (1) Studies of ionospheric structure and irregularities; (2) Study the feasibility of developing better operational ionospheric models for the Air Force; (3) Conduct model/data comparisons in order to validate the ionospheric models; (4) Study plasma convection characteristics in the high-latitude ionosphere; (5) Study magnetosphere-ionosphere coupling problems; (6) Construct a thermospheric general circulation model; (7) Develop a 3D, time-dependent model of the outer plasmasphere; (8) Develop a 3D, time-dependent MHD model of the earth's magnetosphere; (9) Conduct (cont.)

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USU Center of Excellence in Theory and Analysis of the Geo-Plasma Environment

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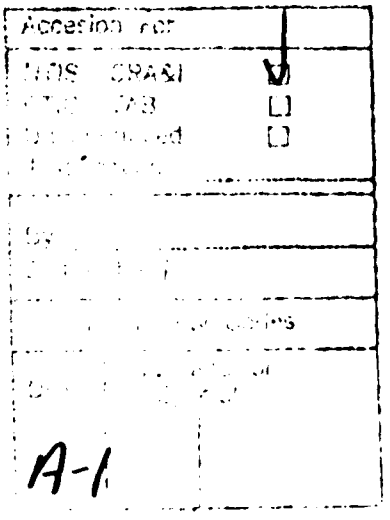

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1. INTRODUCTION

A team of eleven Ph.D. scientists and several graduate students has been assembled at USU in order to establish a 'Center of Excellence in Theory and Analysis of the Geo-Plasma Environment'. The USU scientists work in close collaboration with colleagues at the Air Force Geophysics Laboratories in Bedford, Massachusetts on a number of problems that are relevant to Air Force systems, including OTH radars, communications, and orbiting space structures. The overall goal of the research is to obtain a better understanding of the basic chemical and physical processes operating in the geoplasma environment, including the ionosphere, thermosphere and magnetosphere. Some of the more specific goals are as follows:

1. Investigate the effect of multi-cell convection patterns, plasma blob formation, and multiple arcs on the high-latitude ionosphere.
2. Study the production, transport, and decay of ionospheric irregularities and the associated plasma instabilities.
3. Investigate the coupling of high, middle, and low latitude regions of the ionosphere during the early stages of magnetic storms and substorms.
4. Study the effect of electrodynamic drifts, propagating density fronts, and shock formation on the dynamics of the inner magnetosphere.
5. Construct a numerical model of the earth's upper atmosphere (thermosphere) and couple it to a global ionospheric model.
6. The combined *ionosphere-thermosphere* model is to be used to investigate the effects of plasma convection, particle precipitation, and plasma blobs on the ionosphere-thermosphere system.
7. Couple global models of ionospheric conductivity, electric fields, and currents in order to study seasonal effects, hemispheric asymmetries, and the effects of discrete auroral arcs on ionospheric-magnetospheric dynamics.
8. Investigate ionosphere-magnetosphere coupling in the high-latitude region.

2. ACCOMPLISHMENTS

At the beginning of the first year, several new research positions were advertised and three Ph.D. scientists were subsequently hired to work on the project. In addition, three Air Force students from AWS joined the group to do thesis work related to AWS model applications. A list of the URI personnel is attached.

During the first year, 25 scientific papers have been submitted for publication, 30 presentations have been given at both national and international meetings, and there have been several trips to AFGL and AWS in order to coordinate activities. Lists of publications, presentations, and trips are attached. Also attached are several trip reports.

In March, 1986 five scientists from USU visited AFGL in order to initiate specific collaborative efforts and to better focus the research with regard to Air Force/AFGL interests. As a result of this meeting, several major research thrusts were identified, and the progress we made in these areas during the first year will be described below.

2.1. *Ionosphere Structure & Irregularity Modelling*

Large-scale density structures and irregularities are a common feature in the high-latitude ionosphere. They have been observed in the dayside cusp, polar cap, and nocturnal auroral region over a range of altitudes, including the E-region, F-region, and topside ionosphere. Relative to background densities, the perturbations associated with large-scale density structures vary from about 10% to a factor of 100. These structures can be created by a variety of mechanisms, including particle precipitation in the dayside cusp, in sun-aligned polar cap arcs and in the nocturnal auroral oval; by structured electric fields; and by the breakup of convection patterns. Because of the effect of density structures and irregularities on OTH radars and communications, we studied the origins, lifetimes and transport characteristics with the aid of a three-dimensional, time-dependent ionospheric model. We studied the formation of plasma 'blobs' or 'patches' due to particle precipitation (paper 4); the effect that structured electric fields have on the ionosphere (paper 9); and the lifetimes and transport characteristics of density structures for different seasonal, solar cycle, and interplanetary magnetic field conditions (paper 10). We also studied the extent to which large, magnetic field-aligned ion drifts affect ionospheric density structures (paper 19). The results we obtained are described in the four papers that are enclosed with this report.

2.2. *Operational Ionospheric Models*

Because the Air Weather Service is interested in improving its operational ionospheric models, we have devoted a significant effort toward studying both numerical and empirical models of the ionosphere. We are also trying to develop hybrid models, whereby empirical and numerical approaches are blended to obtain a reliable but efficient ionospheric model. This research has led to eight publications (papers 2, 3, 8, 11, 17, 20, 21, 23). We currently have the only numerical model of the ionosphere that is time-dependent and fully-global, and this model was used to study the seasonal behavior of the global ionosphere at solar maximum (paper 20). We developed an efficient photochemical equilibrium model of ionospheric conductivity that includes the auroral oval (paper 21), and we devised a simple procedure for improving the expression for T_e in the International Reference Ionosphere (IRI) (paper 17). We also investigated alternative statistical models of auroral particle precipitation (paper 2).

We have compared the advantages and disadvantages of using numerical and empirical models of the global ionosphere (papers 3 & 8), and we have described the inputs that are needed in order to model ionospheric climatology and weather (paper 23). In addition, we have written a chapter of a book that presents the complete mathematical description of our numerical ionospheric model (paper 11).

2.3. *Model/Data Comparisons*

In order to determine the validity of our global ionospheric model, we have participated in several world-wide measurement campaigns. One of the programs is called SUNDIAL; 70 ground-based ionosondes and incoherent scatter radars make simultaneous measurements of ionospheric densities, temperatures, and flow velocities during 3-day campaigns. This effort has led to three publications (papers 14–16). We also participated in the MITHRAS campaign, which involved three high-latitude incoherent scatter radars (paper 12) and in the GISMOS campaign (papers 24 & 25). These model/data comparisons were extremely useful not only for verifying ionospheric model predictions, but for determining what model inputs are needed for operational conditions.

2.4. *Plasma Convection Studies*

Convection electric fields have an important effect on the ionosphere at high latitudes. When the interplanetary magnetic field (IMF) is southward, the electric fields act to drive a two-cell pattern of ionospheric circulation, with antisunward flow over the polar cap and return flow equatorward of the auroral oval. However, when the IMF is northward, multiple-cell or severely distorted two-cell convection patterns have been suggested. Using our three-dimensional, time-dependent ionospheric model, we studied the characteristic ionospheric signatures associated with two-, three-, and four-cell convection patterns. Our results indicate that there are major distinguishing ionospheric features associated with the different convection patterns and that these features should be easily observable from sites located in the polar cap (paper 1).

For the case of a northward IMF, the measurements of electric fields are not sufficient to determine whether three-cell, four-cell, or severely distorted two-cell plasma convection patterns exist. Therefore, in an effort to shed light on this problem, we developed an ionospheric electric field model. With measurements of the field-aligned current in the auroral oval and calculated ionospheric conductivities, we were able to calculate plasma convection patterns at F-region altitudes. Our calculations indicate that all of the proposed plasma convection patterns can exist, but at a given time the one that prevails depends on the precise orientation of the IMF (paper 13).

2.5. *Magnetosphere-Ionosphere Coupling*

At high-latitudes the geomagnetic field lines are not dipolar, but instead stretch well beyond the orbit of the moon. Along these so-called 'open' field lines, ionospheric ions (H^+, He^+, O^+) can escape into the magnetospheric tail, which acts to drain the ionosphere and mass-load the magnetosphere. The mass, momentum, and energy coupling associated with this plasma flow was studied in a series of papers (5, 6, 7, 22).

2.6. *Thermospheric General Circulation Model*

At the request of Herb Carlson at AFGL, we have initiated the development of a time-dependent, three-dimensional model of the earth's upper atmosphere (thermosphere). The model is based on a numerical solution of the coupled continuity, momentum, and energy equations for the neutral gas including interactions with ionospheric electrons and ions. Currently, a preliminary version of the thermosphere model is working. Figure 1 shows a sample of the output. For this example, the thermospheric flow over the polar region was uniform at 40 m/s in the antisunward direction. Then, at $t = 0$, a two-cell plasma convection was imposed on the ionosphere and the resultant thermospheric response was calculated. Figure 1 shows the response after one hour. Note that the neutral density, temperature, and wind speed track the two-cell plasma convection pattern.

2.7. *Outer Plasmasphere Model*

We have initiated the development of an outer plasmasphere model. The outer plasmasphere corresponds to the high altitude region at middle and low latitudes that is dominated by dipolar magnetic field lines. Typically, this region is depleted during geomagnetic storms and substorms and then refills via upward plasma flow from the conjugate hemispheres. The model we are developing will describe the refilling process, including the formation and propagation of steep density fronts and shocks. Part of this model development is being done by Gary Wells of AWS, and it was initiated at the request of Dave Anderson of AFGL.

2.8. *MHD Magnetosphere Model*

In support of the work done in the Magnetospheric Physics Branch at AFGL, which is headed by N. Maynard, we have initiated the development of a time-dependent, three-dimensional magnetohydrodynamic model of the earth's magnetosphere. The model is numerical and the appropriate MHD continuity, momentum, and energy equations are solved along with Maxwell's equations for the self-consistent electric and magnetic fields. In the model, a supersonic solar wind plasma flows past the ionized, magnetized environment that surrounds the earth, and as time evolves the magnetosphere forms. At the present time, the full three-dimensional model has been coded, but we are only running the symmetric 2-D version during the current testing phase. Figure 2 shows the electron density distribution surrounding the earth shortly after the hot solar wind plasma impacts the ionized, geomagnetic environment near the earth, which is shown by the dot. For this simulation the solar wind speed was 300 km/s and the solar wind density was 3 cm^{-3}. Only the upper half of the symmetric system is shown; the simulation region is $96 \times 48 R_E$ (earth radii). Note that a bow shock begins to form at the interface of the solar wind and terrestrial plasmas (far left) and that the high-density plasma surrounding the earth is swept past the earth in the antisunward direction.

2.9. *Satellite Drag Studies*

Kelly Hand of AWS is studying certain satellite drag problems for his M.S. degree. Specifically, Kelly Hand's thesis consists of determining the usefulness of using auroral partical precipitation data to improve thermospheric density models so as to obtain a more reliable analysis of satellite drag data. This drag data would consist of (1) orbital elements as tracked by SPACECOM orbital models with the associated atmospheric density model of Jacchia and (2) the relatively higher resolution accelerometer data provided by AFGL. This research necessitated several trips to AWS in Colorado Springs; the trip reports are attached.

2.10. *Spacecraft-Environment Interaction Studies*

Scientists at AFGL, particularly Dr. Cooke, encouraged us to study certain spacecraft-environment interaction problems that are relevant to Air Force interests. We were encouraged to study spacecraft charging, outgassing from orbiting systems, and problems related to high voltage power sources exposed to the space environment. Currently, we are working on problems in all three areas. Mike Dwyer of AWS is conducting a comprehensive literature search on the current state of knowledge of spacecraft charging in low earth orbit (LEO); this effort will lead to an M.S. degree. We have also initiated a model development that will allow us to study the effect on the ionosphere of high voltage (50,000 Volts) sources.

In another effort, we have developed a model which describes the interaction of a large, outgassing, orbiting vehicle with the ambient atmosphere at LEO altitudes. The model uses a finite difference method to solve the Boltzmann equation including the effect of collisions between gaseous particles. Distribution functions are obtained for each of several interacting gas species, and the resuits are presented in terms of macroscopic gas parameters. Figure 3 shows the number densities and temperatures of O, N_2, and H_2O in the vicinity of an outgassing Space Shuttle at LEO altitudes. For this example, the water outgassing rate assumed is approximately that of the Space Shuttle flash evaporator.

3. Future Direction

During the coming year, we will continue to pursue all of the research topics described in the previous section and we expect significant progress. In particular, we anticipate the following:

1. We will continue to study the creation, transport and decay of ionospheric structures. We are currently working on a specific radar data set acquired by H. Carlson, with the goal of modelling a deep electron density trough that appeared to form over the radar. We expect this study to be completed during the coming year.
2. We will continue to study the feasibility of developing hybrid numerical-empirical models that could lead to better operational ionospheric models for the Air Force.
3. We will continue to participate in worldwide measurement campaigns in an effort to further validate our ionospheric and thermospheric models.
4. We will continue to study plasma convection problems, with emphasis on those proposed by N. Maynard at AFGL. In particular, we are currently simulating the ionospheric response to the 'Maynard' distorted 2-cell convection patterns, and we expect this work to be completed in the coming year.
5. We will continue to study a number of magnetosphere-ionosphere coupling problems. We also expect to have completed development of the first 3-D, time-dependent model of plasma outflow from the high-latitude ionosphere.
6. We expect to have the 3D, time-dependent thermospheric circulation model completely developed and we expect to begin studying certain ionosphere-thermosphere coupling problems.
7. We expect to have the 3D, time-dependent model of the outer plasmasphere fully developed.
8. We anticipate that the development of the MHD model of the magnetosphere will be completed and several solar wind-magnetosphere-ionosphere coupling studies will have been initiated.
9. We expect that Kelly Hand will complete his thesis research on satellite drag problems, that Mike Dwyer will complete his thesis on spacecraft charging at LEO altitudes, and that Gary Wells will complete the development of his equatorial ionospheric model.
10. We will continue to study certain spacecraft-environment interaction problems, particularly those related to outgassing and high-voltage power sources.

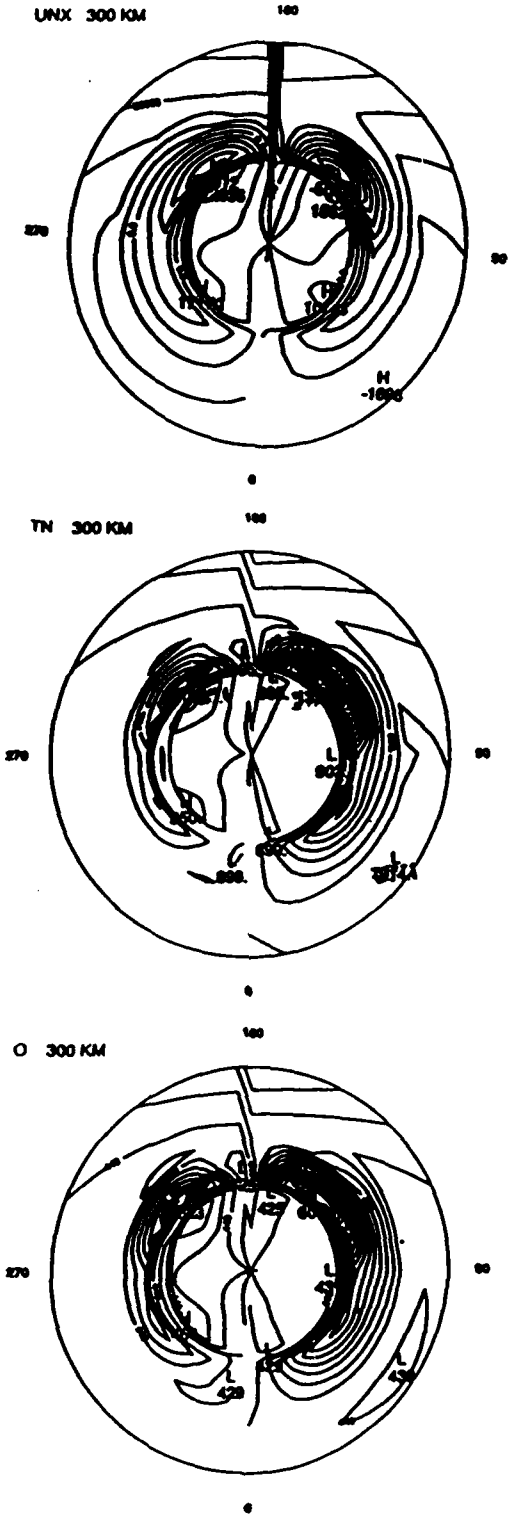

Figure 1. Thermospheric circulation (top panel), temperature (middle panel), and density (bottom panel) at 300 km in the northern polar region. The panels correspond to snapshots one hour after the sudden application of a two-cell plasma convection pattern.

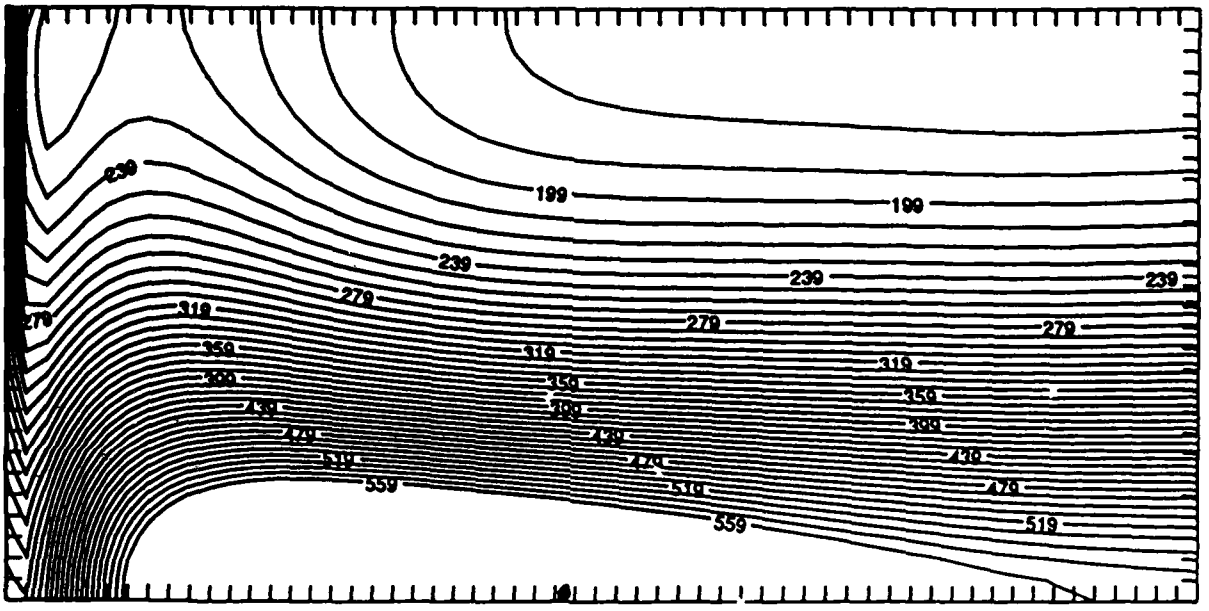

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Figure 2. Plasma density distribution surrounding the earth shortly after the impact of the supersonic solar wind plasma with the high-density, magnetized terrestrial plasma. The earth is shown by the dot.

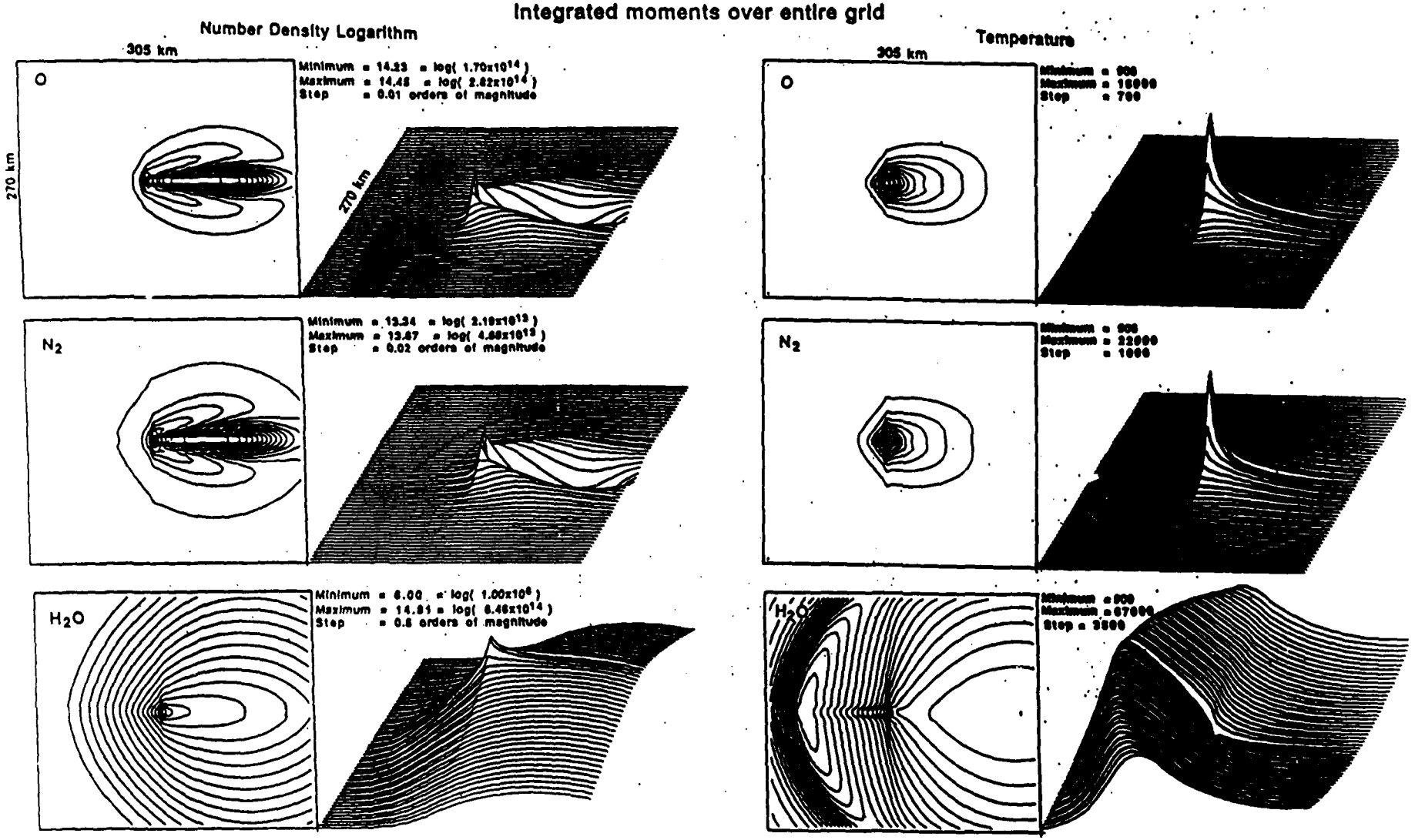

Figure 3. Number density (left panel) and temperature (right panel) of O, N_2, and H_2O in the vicinity of an outgassing Space Shuttle at LEO altitudes.

URI Personnel

Ph.D. Scientists

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Administrative Support

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URI Publications

1. J. J. Sojka and R. W. Schunk, Theoretical study of the high latitude ionosphere's response to multi-cell convection patterns, *J. Geophys. Res., 92*, 8733–8744, 1987.

2. M. Bowline, J. J. Sojka, and D. S. Evans, Investigation into Alternative statistical auroral oval models, Stage I., *CASS Report CASS-87-01*, 1987.

3. A. F. Nagy and R. W. Schunk, Ionosphere, In "Encyclopedia of Physical Science and Technology", *Vol. 7*, 19–33, 1987.

4. R. W. Schunk and J. J. Sojka, Ionospheric features induced by magnetospheric processes, In *Quantitative Modeling of Magnetosphere-Ionosphere Coupling Processes*, 11–16, Kyoto Sangyo University, Japan, 1987.

5. H. G. Demars and R. W. Schunk, Temperature anisotropies in the terrestrial ionosphere and plasmasphere, *Rev. Geophys.*, in press.

6. R. W. Schunk, The polar wind, *Proceedings of the Huntsville Workshop on Magnetosphere/Ionosphere Plasma Models*, in press.

7. A. R. Barakat, R. W. Schunk, T. E. Moore, and J. H. Waite, Jr., Ion escape fluxes from the terrestrial high latitude ionosphere, *J. Geophys. Res.*, in press.

8. R. W. Schunk and E. P. Szuszczewicz, First-principle and empirical modelling of the global-scale ionosphere, *Ann. Geophysicae*, in press.

9. J. J. Sojka and R. W. Schunk, A model study of how electric field structures affect the polar cap *F*-region, *J. Geophys. Res.*, in press.

10. R. W. Schunk and J. J. Sojka, A theoretical study of the lifetime and transport of large ionospheric density structures, *J. Geophys. Res.*, in press.

11. R. W. Schunk, A mathematical model of the middle-high latitude ionosphere, *Special Issue of PAGEOPH*, 'Mathematical Modelling of the Ionospheric and Thermospheric Processes', in press.

12. C. E. Rasmussen, J. J. Sojka, R. W. Schunk, V. B. Wickwar, O. de la Beaujardiere, J. Foster, and J. Holt, Comparison of simultaneous Chatanika and Millstone Hill

temperature measurements with ionospheric model predictions, *J. Geophys. Res.*, in press.

13. C. E. Rasmussen and R. W. Schunk, Ionospheric convection inferred from IMF dependent Birkeland currents, *J. Geophys. Res.*, in press.

14. E. P. Szuszczewicz, E. Roelof, R. W. Schunk, B. Fejer, R. Wolf, R. Leitinger, M. Abdu, B M. Reddy, J. Joselyn, P. J. Wilkinson, and R. F. Woodman, SUNDIAL: A worldwide study of interactive ionospheric processes and their roles in the transfer of energy and mass in the sun-earth system, *Ann. Geophysicae*, in press.

15. M. A. Abdu, B. M. Reddy, G. O. Walker, R. Hanbaba, J. H. A. Sobral, B. G. Fejer, R. F. Woodman, R. W. Schunk, and E. P. Szuszczewicz, Processes in the quiet and disturbed equatorial low latitude ionosphere: SUNDIAL campaign 1984, *Ann. Geophysicae*, in press.

16. P. J. Wilkinson, R. W. Schunk, and R. Hanbaba, Interhemispheric comparison of SUNDIAL *F*-region data with global-scale ionospheric models, *Ann. Geophysicae*, in press.

17. J. J. Sojka, R. W. Schunk, and M. D. Bowline, Modelled ionospheric T_e profiles at mid-latitudes for possible IRI application, *Adv. Space Res.*, in press.

18. R. W. Schunk, Interactions between the polar ionosphere and thermosphere, *Physica Scripta*, in press.

19. R. J. Sica, C. E. Rasmussen, and R. W. Schunk, Can the high latitude ionosphere support large field-aligned ion drifts? *J. Atmos. Terr. Phys.*, in press.

20. J. J. Sojka and R. W. Schunk, Theoretical study of the seasonal behavior of the global ionosphere at solar maximum, *J. Geophys. Res.*, submitted.

21. C. E. Rasmussen, R. W. Schunk, and V. B. Wickwar, A photochemical equilibrium model of ionospheric conductivity, *J. Geophys. Res.*, submitted.

22. R. W. Schunk, Polar wind theory, *Proceedings of the 1987 Cambridge Workshop in Theoretical Geoplasma Physics*, submitted.

23. R. W. Schunk and J. J. Sojka, Numerical simulations of the ionosphere: Climatology and weather, *EOS*, submitted.

24. J. F. Providakes, D. T. Farley, B. G. Fejer, J. Sahr, W. E. Swartz, I. Haggstrom, A. Hedberg, and J. Nordling, Observations of auroral *E*-region plasma waves and electron heating with EISCAT and VHF radar interferometer, *J. Atmos. Terr. Phys.*, submitted.

25. B. G. Fejer, M. C. Kelley, C. Senior, O. de la Beaujardiere, J. A. Holt, C. A. Tepley, R. Burnside, J. H. A. Sobral, R. F. Woodman and R. Lepping, Low and mid-latitude ionospheric electric fields during the January 1984 GISMOS campaign, *J. Geophys. Res.*, to be submitted.

URI Presentations

1. *R. W. Schunk*, The polar wind, *Invited Review*, Presented at "The First Huntsville Workshop on Magnetosphere-Ionosphere Plasma Models", October 13–16, 1986; Huntsville, Alabama.

2. *A. R. Barakat*, R. W. Schunk, T. E. Moore, and J. H. Waite, Ion escape fluxes in the terrestrial high latitude ionosphere, Presented at "The First Huntsville Workshop on Magnetosphere Ionosphere Plasma Models", October 13–16, 1986; Huntsville, Alabama.

3. *R. W. Schunk*, Ionosphere-thermosphere modelling: Current status, *Invited Review*, Presented at the International Symposium on Large-Scale Processes in the Ionospheric-Thermospheric System, December 2–5, 1986; Boulder, Colorado.

4. *C. E. Rasmussen*, R. W. Schunk, J. J. Sojka, V. B. Wickwar, O. de la Beaujardiere, J. C. Foster, and J. M. Holt, Comparison of simultaneous Chatanika and Millstone Hill temperature measurements with ionospheric model predictions, "International Symposium on Large-Scale Processes in the Ionospheric-Thermospheric System", December 2–5, 1986; Boulder, Colorado.

5. *J. J. Sojka*, and R. W. Schunk, Asymmetries in the plasma characteristics of the conjugate high-latitude ionospheres, "International Symposium on Large-Scale Processes in the Ionospheric-Thermospheric System", December 2–5, 1986; Boulder, Colorado.

6. *C. E. Rasmussen*, and R. W. Schunk, An E and F region density model for obtaining ionospheric conductivity, "International Symposium on Large-Scale Processes in the Ionospheric-Thermospheric System", December 2–5, 1986; Boulder, Colorado.

7. *E. P. Szuszczewicz*, E. Roelof, R. W. Schunk, B. Fejer, R. Wolf, R. Leitinger, M. Abdu, B M. Reddy, J. Joselyn, P. J. Wilkinson, and R. F. Woodman, SUNDIAL: A continuing program of global-scale modeling and measurement of ionospheric responses to solar, magnetospheric, and thermospheric controls, "International Symposium on Large-Scale Processes in the Ionospheric-Thermospheric System", December 2–5, 1986; Boulder, Colorado.

8. *H. G. Demars*, and R. W. Schunk, Comparison of solutions to bi-Maxwellian and Maxwellian transport equations for subsonic flows, AGU Fall Meeting, San Francisco, California; *EOS, 67*, 1136, 1986.

9. *A. R. Barakat*, and R. W. Schunk, Stability of the polar wind, AGU Fall Meeting, San Francisco, California; *EOS, 67*, 1136, 1986.

10. *J. J. Sojka*, and R. W. Schunk, Theoretical study of the high latitude ionosphere's response to multi-cell convection patterns, AGU Fall Meeting, San Francisco, California; *EOS, 67*, 1137, 1986.

11. *R. J. Sica*, C. E. Rasmussen, and R. W. Schunk, Can the high latitude ionosphere support large field-aligned ion drifts? AGU Fall Meeting, San Francisco, California; *EOS, 67*, 1137, 1986.

12. *R. W. Schunk*, and J. J. Sojka, The lifetime and transport of severe ionospheric disturbances, AGU Fall Meeting, San Francisco, California; *EOS, 67*, 1137, 1986.

13. *C. E. Rasmussen*, and R. W. Schunk, Ionospheric convection driven by NBZ currents, AGU Fall Meeting, San Francisco, California; *EOS, 67*, 1162, 1986.

14. *C. E. Rasmussen*, and R. W. Schunk, Ionospheric convection driven by asymmetries in NBZ currents, National Radio Science Meeting, January 12–15, 1987; Boulder, Colorado.

15. *R. W. Schunk*, Implications of the SUNDIAL data on first-principles global-scale models, Presented at the "Third SUNDIAL Workshop", February 24–27, 1987; La Jolla, California.

16. *R. W. Schunk*, and J. J. Sojka, Ionospheric features induced by magnetospheric processes, *Invited Talk*, Presented at the International Symposium on Quantitative Modeling of Magnetosphere-Ionosphere Coupling Processes, March 9–13, 1987; Kyoto, Japan.

17. *E. P. Szuszczewicz*, E. Roelof, R. W. Schunk, B. Fejer, R. Wolf, M. Abdu, J. Joselyn, B. M. Reddy, P. Wilkinson, R. Woodman, and R. Leitinger, SUNDIAL: A global study of ionospheric processes and their roles in the transfer of energy and mass in the sun–earth system, AGU Spring Meeting, Baltimore, Maryland; *EOS, 68*, 364, 1987.

18. *R. W. Schunk*, and E. P. Szuszczewicz, First-principle and empirical modeling of the global-scale ionosphere, *Invited Talk*, AGU Spring Meeting, Baltimore, Maryland; *EOS, 68*, 364, 1987.

19. P. J. Wilkinson, *R. W. Schunk*, R. Hanbaba, and E. P. Szuszczewicz, Interhemispheric comparison of SUNDIAL *F*-region data with global-scale ionospheric models, AGU Spring Meeting, Baltimore, Maryland; *EOS, 68*, 364, 1987.

20. *M. A. Abdu*, B. M. Reddy, G. O. Walker, R. Hanbaba, J. H. A. Sobral, B. G. Fejer, R. W. Schunk, R. F. Woodman, and E. P. Szuszczewicz, Processes in the quiet and disturbed equatorial low latitude ionosphere: SUNDIAL campaign 1984, AGU Spring Meeting, Baltimore, Maryland; *EOS, 68*, 364, 1987.

21. *R. W. Schunk*, Characteristics of high voltage spheres in the ionosphere, Presented at the SPEAR meeting, W. J. Schafer, Inc., July 30, 1987; Arlington, Virginia.

22. *R. W. Schunk*, Polar wind theory, *Invited Review*, Presented at the 1987 Cambridge Workshop in Theoretical Geoplasma Physics on "Ionosphere-Magnetosphere-Solar Wind Coupling Processes", July 28–August 1, 1987; Cambridge, Massachusetts.

23. *R. W. Schunk* and E. P. Szuszczewicz, First-principal and empirical modelling of the global-scale ionosphere, Presented at the International Union of Geodesy and Geophysics, Vancouver, Canada; August 9–22, 1987.

24. *R. J. Sica*, C. E. Rasmussen, and R. W. Schunk, Can the high-latitude ionosphere support large field-aligned ion drifts?, Presented at the International Union of Geodesy and Geophysics, Vancouver, Canada; August 9–22, 1987.

25. *C. E. Rasmussen* and R. W. Schunk, Ionospheric convection driven by NBZ currents, Presented at the International Union of Geodesy and Geophysics, Vancouver, Canada; August 9–22, 1987.

26. *A. R. Barakat* and R. W. Schunk, Stability of the polar wind: Linear theory and simulation, Presented at the International Union of Geodesy and Geophysics, Vancouver, Canada; August 9–22, 1987.

27. *C. E. Rasmussen* and R. W. Schunk, An *E*- and *F*-region density model for obtaining ionospheric conductivity, Presented at the International Union of Geodesy and Geophysics, Vancouver, Canada; August 9–22, 1987.

28. *C. E. Rasmussen*, J. J. Sojka, R. W. Schunk, V. B. Wickwar, O. de la Beaujardiere, J. Foster, and J. Holt, Comparison of simultaneous Chatanika and Millstone Hill temperature measurements with ionospheric model predictions, Presented at the

International Union of Geodesy and Geophysics, Vancouver, Canada; August 9–22, 1987.

29. *J. J. Sojka*, New results in modelling the global and high latitude ionospheric dynamics, Presented at the International Union of Geodesy and Geophysics, Vancouver, Canada; August 9–22, 1987.

30. *J. J. Sojka*, L. A. Frank, and J. D. Craven, Global scale auroral imagery, an essential tool for ionospheric simulation and prediction, Presented at the International Union of Geodesy and Geophysics, Vancouver, Canada; August 9–22, 1987.

URI Travel Summary

1. Intl Workshop- Large Scale Processes in the Ionosphere/Thermosphere
   Boulder, Colorado
   12/1–12/5
   Schunk, Rasmussen, and Sojka presented papers.

2. Fall American Geophysical Union Meeting
   San Francisco, California
   12/7–12/12
   Schunk, Barakat, Rasmussen, Demars, and Bowline presented papers.

3. URSI International Meeting
   Boulder, Colorado
   1/11–1/13
   Schunk and Rasmussen presented papers.

4. SUNDIAL Meeting
   San Diego, California
   2/23–2/27
   Schunk- to compare ionospheric model predictions with measurements.

5. AFGL Meeting
   Boston, Massachusetts
   3/29–4/1
   Initiate cooperative efforts betwen USU & AFGL scientists.
   Presentations made:
   Schunk - Overview of the USU Center of Excellence in Theory and Analysis of the Geoplasma Environment.
   Sojka - Status of Large Scale Ionospheric-Thermospheric Modelling at USU.
   Barakat - Stability of the Polar Wind
   Rasmussen - Modeling of Plasma Convection in the High-Latitude Ionosphere.
   Raitt - Experimental Space Plasma Physics

6. Meeting with Dave Evans (See attached trip reports)
   Boulder, Colorado
   4/27–4/29
   Sojka and Hand

7. Spring American Geophysical Union Meeting
   Baltimore, Maryland
   5/17–5/20
   Schunk presented papers.

8. AFGL Meeting
   Boston, Massachusetts
   6/17–6/20
   Sojka meeting to discuss collaborative projects.

9. CEDAR/GISMOS Workshop
   Boulder, Colorado
   6/25–6/29
   Schunk, Sojka, and Sica meetings to compare ionospheric model predictions with measurements.

10. AFOSR Supported Research
    Colorado Springs, Colorado
    6/29–7/2
    Hand attended satellite drag meeting.

11. AFGL Meeting
    Boston, Massachusetts
    7/12–7/14
    Rasmussen attended meetings to discuss collaborative projects.

12. AFGL Meeting
    Boston Massachusetts
    7/26–8/2
    Schunk, Sica, and Yang attended meetings to discuss collaborative projects with H. Carlson, E. Weber, Bauchau, J. Whalen, C. Sherman, and S. Basu.
    Schunk and Yang attended MIT Cambridge Workshop and presented papers.
    Schunk also attended the Soviet Ionospheric Modification Workshop, Spacecraft Contamination Meeting, and SUNDIAL Meeting in Washington, D. C.

13. IAGA International Meeting
    Vancouver, Canada
    8/16–8/21
    Schunk, Sojka, Rasmussen, and Barakat presented papers.

14. TEX Macro Workshop
    Chicago, Illinois
    9/13–9/18
    Selzer attended workshop on macro writing for final typeset copy.

15. AFOSR Supported Research
    Colorado Springs, Colorado
    10/18–10/10/21
    Hand attended meetings on satellite drag.

16. AFOSR Supported Research
    Boston, Massachusetts
    10/19–10/22
    Schunk attended workshop on atmospheric density and aerodynamic drag models for Air Force operations.

Appendix

Trip Reports

TRIP REPORT

SPACE ENVIRONMENT LABORATORY
325 BROADWAY
BOULDER, CO 80303
April, 1987

ATTENDEES: Dr. Dave Evans, Dr. Jan Sojka, Capt. Kelly Hand

PURPOSE: To gain further insight into the NOAA/TIROS particle precipitation data which will be used for the thesis research, and to set up for aquisition of the data to be used for the research.

I gave Dr. Evans an overview of the thesis proposal and the objectives to be accomplished. Specifically, I told him the thesis consisted of determining the usefulness of particle precipitation data as an input to the various thermospheric density models via the analysis of satellite drag data. This drag data would consist of (1) orbital elements as tracked by SPACECOM orbital models with the associated atmospheric density model (Jachia) and (2) the relatively higher resolution accelerometer data provided by AFGL.

Dr. Evans explained how he interpolated the data and gave us an outline of normalization procedures. This normalization was necessary because data from different satellites at different locations and times sampled the particle precipitation. He also pointed out that a study done by Fuller-Rowell could be applied to take into account the Joule heating factor. In the Fuller-Rowell study, a somewhat empirical relationship between particle precipitation and Joule heating was established. It was Dr. Evan's opinion that this work should apply to this study. This would obviously simplify our approach, since the particle precipitation index would yield Joule heating, and hence, both major auroral heating sources would be described.

Dr. Evans cited three studies which point to the potential of a particle precipitation parameter, as opposed to the current magnetic indicies in thermospheric density modeling:

1. A report by S. Maeda entitled "Numerical Simulations of Thermospheric Disturbances Excited by Magnetic Energy Input" demonstrated the potential of the parameter. This parameter and MIT electric field data provided the magnetospheric energy input to an empirical thermospheric model. The model showed an excellent case study which compared actual against modeled exospheric temperatures. The model demonstrated that particle precipitation energy has the potential of standing on its own as the driver for the geomagnetic portion of the thermospheric energy input.

2. Coster (private communication) showed a graph which plotted observed deviations from predicted orbits of spherical satellites, and it gives a correlation coefficient for each of three parameters: F10.7, Kp, and the particle precipitation index. The results (which were computed over a 75 day period) showed consistently low correlation (no correlation with F10.7) with all indicies EXCEPT particle precipitation.

3. Another study showed the LACK of correlation between the conventional magnetic field indicies (Kp, Ap, Ae) and particle precipitation. This indicates that the magnetic field indicies do not accurately track the energy input into the thermosphere. Also, this lack of correlation indicates that the new particle precipitation index is independent of the previous indicies.

Dr. Evans then provided us with tabular data giving the hemispheric power input as a function of time as well as the associated precipitation index, Ap and Kp. He also committed to send us the complete data set on

tape, along with his global auroral average model of the energy flux and Joule heating.

TRIP REPORT

DIRECTORATE OF OPERATION ANALYSIS
AIR FORCE SPACE COMMAND
COLORADO SPRINGS CO 80914

28 APRIL 1987

ATTENDEES: Dr. Liu, Dr. Wackernagel, Lt. Col. Sundberg, Lt. Col. Davenport

PURPOSE: To meet with Dr. Liu, who works with the Directorate of Analysis at Space Command, to define our thesis objectives and gain support from him pertaining to the research.

I explained the thesis proposal, that of determining the usefulness of a particle precipitation parameter (PPE) as an input to the geomagnetic part of upper atmospheric density models via analysis of satellite drag data. The specific drag data being (1) the orbital drag data which SPACECOM has at their disposal and (2) AFGL accelerometer data.

I showed the potential of the PPE parameter by pointing out the various studies mentioned in the Boulder trip report as well as by pointing to the studies that they did themselves in analyzing the various density models.

We determined that a good place to start the study would be to input the PPE parameter as it is to the SALT orbital model via the Jachia atmospheric density model. We discussed that this may not produce favorable results at all because of the way in which the Jachia model was constructed and the lack of correlation between Kp and the PPE index.

From this realization, support was given to the second study, that of using the higher resolution accelerometer drag data. This would provide a much better indication of the physical processes taking place, thus

providing impetus to the thesis recommendation of rebuilding empirical models using this new parameter.

Dr. Liu showed us the atmospheric subroutine that the orbital model uses to get densities from the Jachia model. I am tasked with creating a subroutine which will allow input of the PPE index to the density model. This would allow a side by side comparison of the PPE as an input verses Kp. Another possibility would be the "fudging" of the density output through the use of the PPE parameter, which the Maeda study demonstrates may have merit (see chart on the last page).

A subsequent visit was deemed necessary based on the fact that the orbital model was one of the tools we need to use. Since they are going to be moving sometime in August or September they mentioned the best time would be early this summer.

In order to expedite our use of the AF SPACECOM orbital software, Lori McCarter was designated the POC.

Dr. Liu, Dr. Wackernagel, Lt. Col. Sundberg, and Lt. Col. Davenport are very enthused about our work and are looking forward to assisting us in any way they can.

Figure 7 shows a comparison between the simulated exospheric temperature at 55 degree geographic latitude and the temperature observed by the Millstone Hill radar during the same period of time (provided by Oliver). The temperature at Millstone Hill was derived by subtracting the quite-time daily variation. The agreement between those two temperatures seems to be good in terms of the absolute magnitude of the temperature variations and the time constants for those variations. The difference that can be seen at the short time variations may be caused by the fact that the observed temperature still has a local time effects as well as the effects of the changing geomagnetic activity.

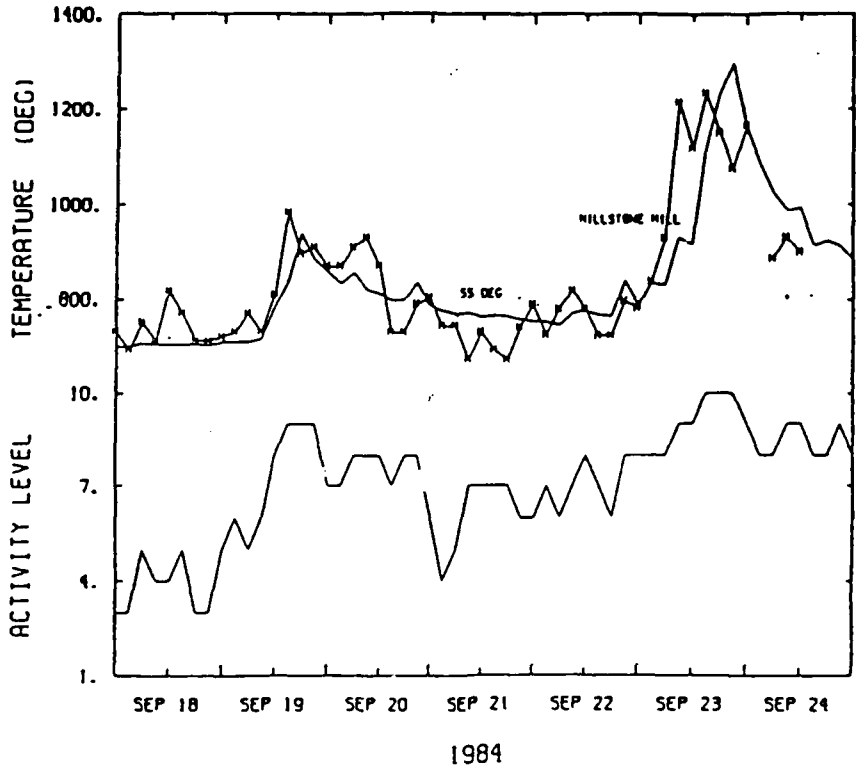

Figure 7 A comparison between the simulated temperature at 55 degree geographic latitude and the temperature observed by the Millstone Hill radar.

All the results presented here indicate the upper thermosphere is significantly controlled by the magnetospheric/ionospheric processes not only at the high-latitudes but also at the mid- and low-latitudes. The compotion of ionization is not updated consistently with the neutral composition change. In furture programs, the entire coupling between the neutral and ionized gases should be taken into account.

REFERENCES

(1) T. Fuller-Rowell et al. 1986 The 6th International Symposium on solar-terrestrial physics of SCOSTEP.
(2) J.C. Foster et al. 1986 Geophysical Research Letter, 13, 656.
(3) Y.T. Chiu 1975 J. Atmos. Terr. Phys., 37, 1563.
(4) T. Fuller-Rowell 1984 J. Geophys. Res.,89, 2971.
(5) R.G. Roble and B.A. Emery 1983 Planet. Space Sci., 31, 597.
(6) T.E. Cravens 1981 J. Geophys. Res., 86, 5710.

UTAH STATE UNIVERSITY · LOGAN, UTAH 84322-3400

Center for Atmospheric and Space Sciences
Telephone (801) 750-2961
TELEX 3789426

May 7, 1987

Mr. Frank Marcos
AFGL/LIS
Hanscom AFB, MA 01731-5000

Dear Mr. Marcos:

This letter pertains to my thesis research on using particle precipitationenergy (PPE) as an index for density models. I would also like to set up a meeting with you in order to use your expertise and your accelerometer data. Enclosed you will find some highlights of the recent visit I and Dr. Sojka had with Dr. Evans (SEL) and Dr. Liu (SPACECOM).

The thesis proposal is that a particle precipitation parameter would improve the modeling of atmospheric densities over the current method using magnetic indicies. A test of this proposal would consist of using NOAA/TIROS particle precipitation data as an input to a drag model and comparing it with that of actual satellite drag data.

The specific data I am referring to is orbital data at Space Command, and the accelerometer data which you have at your disposal. In meeting with Dr. Liu, he enthusiastically agreed to support our efforts through the use of his orbital model which is fed densities via the Jachia 70. Jan and I agreed that a straight input into the model may not yield favorable results, based on the construction of the model, but nevertheless, we are going to do the test and run side by side comparisons of the existing SPACECOM orbital software with a revised version using the PPE index.

To gain actual physical insight into the parameter and its affects on total mass density will require a much higher resolution approach than the preceeding test and would require use of your accelerometer data. In speaking with Dr. Sojka I've gathered that the best way to approach the use of your data would be to use periods for which accelerometer data has already been prepared. In that regard, could you please inform me of the periods after 1978 for which high resolution drag data has been analyzed. The 1978 start date arises due to the fact that this is the period during which PPE data is available.

If you feel sufficient data is available, I could probably come to AFGL this summer to work with you as part of Dr. Schunk's USU Center of Excellence in Theory and Analysis of the Geo-plasma Environment. Could you provide me with any information about your data which would familiarize me with how I

may best be prepared to implement comparisons with the particle precipitation data.

I am looking forward to hearing from you and working with you on this project.

Enclosed are copies of our trip report to Boulder and Colorado Springs.

Sincerely,

Kelly J. Hand, Capt., USAF

UTAH STATE UNIVERSITY · LOGAN, UTAH 84322-3400

Center for Atmospheric and Space Sciences
Telephone (801) 750-2961
TELEX 3789426

May 7, 1987

Dr. Dave Evans
R/E/SEL
325 Broadway
Boulder, CO 80303

Dear Dave:

This letter is to follow up on our recent visit, and to give you some specifics on where to send the data. Again I want to thank you for the time you spent with Dr. Sojka and myself on 27 April. That meeting was not only productive from the standpoint of my education concerning your data, but you also provided us with additional evidence to gain support from Space Command on the project.

Our visit to Space Command the following day was also very productive. With the evidence we had for the potential application of your data in improving satellite drag, we were able to gain access to the orbital data which would show the application first hand. At the meeting, we realized that the initial results may not be favorable based on the construction of the Jachia model, but we will proceed to do that test anyway. We will then follow on with more highly resolved accelerometer data. This will obviously give us a better indication of the effect this energy has on low orbit densities, and provide us with impetus in making the recommendation to rebuild thermospheric density models based on this parameter.

I am looking forward to recieving the data from you. As discussed, I would like your PPE values and activity indicies, along with the Kp and Ap values from November 1978 on. In addition, we would be interested in obtaining your global auroral and global Joule heating models as a function of the activity index. An ASCII, 1600 BPI tape would be ideal, however, integer format data would also be very manageable. Please send it to: Dr. Jan Sojka or Kelly Hand, Center for Atmospheric and Space Sciences, USU, Logan, Utah 84322-4405. Again, thank you for your time and direction.

Enclosed are copies of our trip report to Boulder and Colorado Springs.

Sincerely,

Kelly J. Hand, Capt., USAF
AFIT Student

UTAH STATE UNIVERSITY · LOGAN, UTAH 84322-3400

Center for Atmospheric and Space Sciences
Telephone (801) 750-2961
TELEX 3789426

May 7, 1987

Dr. Joseph Liu
Directorate of Analysis
of Spacecom/DOA
Stop 7
Peterson AFB, CO 80914-5001

Dear Dr. Liu:

This letter is to follow up on our recent visit to Space Command pertaining to my thesis research, and to set up future interactions on the subject. I was very pleased with the results of the visit, and I appreciate the time you and Dr. Wackernagel spent with my advisor, Dr. Jan Sojka, and myself.

In our meeting we demonstrated to you the potential of the particle precipitation parameter in improving the modeling of upper atmospheric densities, and therefore improving satellite drag calculations. We also pointed out that to further prove the utility of the parameter we needed to perform some tests on some actual orbital data as well as AFGL accelerometer data. Two immediate tasks were identified:

1. Set the orbital limits: the particle precipitation energy input would have maximal effect over a certain altitude range as well as being most acute over the auroral latitudes. This forces us to constrain ourselves to certain orbits. In the attached table you will find the list of the limits which will apply to this study, and the reasons for those limits. With these constraints I leave it to you and Dr. Wackernagel to select a subset of suitable orbits for the tests.

2. Prepare the data: we also discussed the fact that to use your orbital data would mean a future trip for me to Colorado Springs. In order to make the trip as productive as possible, the data must be ready for implementation when I arrive. To allow this, I am now in the process of writing a subroutine which will put the PPE data in a format acceptable to the atmospheric density model. As soon as that task is finished and the data is in place I will be ready for the visit.

When I am ready with everything I will let you know in order to set up that visit. I am looking forward to working with you on this project, as the

results promise not only to advance our knowledge of the space environment, but also give the practical possibility of improving orbital analysis.

Sincerely,

Kelly J. Hand, Capt., USAF
AFIT Graduate Student

TABLE 1

1. Period of interest that PPE data is available: Nov 78 - 1986.

2. MSIS model indicates densities increase at all altitudes above 120 km when Ap is increased (see attached figure). Since maximum drag occurs at perigee I would like to have perigee as deep in the atmosphere as possible: 150 km to 400 km would be excellent.

3. Eccentric orbits are better than circular orbits because they allow the region of most intense drag to be identified. Satellite with perigee in different regions would be ideal. Therefore, I would like to be able to partition the orbits by perigee location, so if you can give me the geographic location of the perigee, that would be great. It would be even better if you could supply me with geomagnetic coordinates, but if that is inconvenient, don't bother.

4. To some extent, the time frames of interest depend upon the time periods of disturbed and quiet geomagnetic conditions. Once I obtain the required data set from Dr. Evans I will be able to supply you with those times of interest.

SUMMARY OF DATA REQUIREMENTS:

1. General Period: Nov 78 - 1986.

2. Altitudes: 150 - 400 km.

3. Orbit Geometry: Prefer eccentric (provide perigee location).

4. Specific Periods: I will get back with you concerning those.

June, 18-19, 1987

AFGL Trip Report - J. J. Sojka

I visited several scientists within two divisions, (4 groups) in the two day visit (18 and 19 June 1987). The substance and implications of these meetings are listed below.

Thursday 18th; Bill Denig.

He is currently being transferred from Charlie Pike's group to Nelson Maynard's group in response to his request to be more active in science. In the late fall he plans to visit USU for one or two weeks to follow up ideas on storm dynamics modelling. Working with Nelson's group Bill will have access to data sets which should be able to better define a storm set of boundary conditions (3 hours).

Thursday 18th; Dave Anderson.

Dave showed me (pre-print available) his current work on dynamics convection control of solar EUV produced plasma entering the polar cap. He has run two convection trajectories for two different polar cap diameters. One allows solar EUV produced plasma to get to Thule, while the other has plasma originating in the polar cap. By "flipping" between these states he sees patches. The densities look similar to those observed by the ionosonde located at Thule.

Dave has also put the SLIM model into a coefficient data base for insertion into the CHIU formulation. Gary should follow up and get this package. It will also be useful for thermosphere modelling applications.

Dave has received the tape and we discussed what he is going to do with the data base. (1 hour meeting).

Thursday 18th; Howard Singer.

He is enthusiastic about working with Craig. (10 minutes).

Thursday 18th; Ed Webber.

He is refereeing the structures paper. Was very enthusiastic and wants to follow up this work. His feeling is that the structures are elongated all the way across the polar cap. He showed me a rocket data set across polar cap arc. The data set contained all the relevant parameters and showed the expected correlations. (30 minutes).

Thursday 18th; Jorgen Buchau.

Talked at some length about differences between their ionosondes and Tom Berkey's. Already the Thule (Buchau) radar gets plasma drift velocities which appear in good agreement with our expectations. This is achieved using Doppler + phase information. But somehow Tom's HF radar does not really have this full capability. (got a reprint) (30 minutes.)

Thursday 18th; Jim Whalen.

Showed me his current UT longitude trough data. Looks like something which is already in our models. He sees density diurnal variations which are UT dependent in the geographic frame but invariant in the MLT frame for stations at 70° geo. latitude. This looks really simple but his data sets show up the ± 1 $1/2 \rightarrow \pm 2$ modulation with longitude. The effect is described in a preprint. I plan to follow this work up with Jim. (1 hour).

June 18th; Frank Marcos.

We talked about the potential data analysis conflicts. He gave me a history which outlined his concerns. During the meeting we were able to come up with a workable project which fits in with Kelly Hand's time scale. Basically the last two weeks of July Kelly can go to AFGL and help Frank check out the precipitation index. Kelly can contribute by taking the index + software to AFGL. (3/4 hour) (3 reprints).

June 19th; Dave Hardy.

We considered the question of discrete precipitation in the polar cap during periods of B_z north. The statistical model definitely does not contain it. In fact the structures all get smoothed out causing the backgrounds to be a little high. Dave gave me a set of auroral energy flux and number flux coefficients which can be put into the conductivity model from Fred Rich. I will get this done and generate some contour plots. (Spent about 1 1/4 hours) (got 3 reprints).

June 19th; Fred Rich.

Met to talk about Heppner/Maynard convection patterns. I got copies of large blown up versions, which I promised we would digitize and send back to AFGL these data sets.

Other than this we talked about future uses of DMSP-Hilat synchronize passes to look at aurora trough boundaries.

June 19th; Nelson Maynard.

Met and talked through the paper contrasting 2 cells distorted and multiple cells. For the start conditions decided to use Kp = 1, $B_z, 15\gamma$ B_y positive $\sim 15\gamma$ and F10.7 = 170 solar max 30 days before solstice. Data sets should be available for comparison. The B_y negative case would be done later or only the distorted two cells B_y negative might need to be done. If it seems useful at a later stage the discrete structure may be entered into the polar cap precipitation system. I will put together trajectories and oval and let Nelson see them. (met for 2 hours)

June 19th; Herb Carlson.

We met for about an hour and talked about general status and short term goals in relation to the prime importance of the model development and secondary objectives. Herb has a "pet" EISCAT data set and is interested in following up with a theoretical model study of the trough formation mechanism. It seems that the composition and ion temperature data will be available as well as velocities and densities. It probably would not be too difficult to work this in after Nelson's study.

Summary. Major 2 objectives were met. Got the Multi-cell 2 cell distorted study well under way, as well as getting Kelly Hand set up for a trip. In addition I probably met everyone we hope to interact with at AFGL.

Kelly Hand

Trip Report

Space Command/Directorate of Analysis (DOA)

Colorado Springs, Co

29 Jun - 2 Jul 1987

Purpose: To determine the utility of particle precipitation energy (PPE) to improve the operational capability of predicting satellite orbital elements, and thus improving the modeling of upper atmospheric density, via the replacement of the Ap in the Jachia 70 (ATMSP) of DOA's orbital element generation program.

Discussion: The following is a log of what was discussed and accomplished.

29 Jun:

1. Gave an outline of the objective of the project to Dr. Liu, Dr. Wackernagel, Ms. Lori McCarter, Capt Carl Crockett, Mr. Bob Morris, Mr. Tim Payne, and Mrs. Brenda Simmons. The following is a list of the subobjectives along with the various limitations and suggestions provided by the DOA personnel listed above:

A. Analysis of auroral region perigee orbits:

(1) Inclinations must be limited to geographic latitudes greater than 55 degrees. This would assure auroral zone intersection.

(2) Eccentricities must be moderate to provide the required resolution of perigee atmospheric passage.

(3) Periods must be chosen to assure that the perigee is within the required latitude limits.

(4) Latitude limits must be approximate auroral zone limits (55–75 degrees geographic).

(5) Altitude of periapsis must be less than 600 km.

(6) Results would come from the comparison of the RMS of the residuals from the

differential correction method.

B. Analysis of equatorial regions: If A6 was positive we would move on to this test.

(1) Periapsis limited to low latitudes (30 degrees north/south).

(2) Time lag for the heat transfer may need to be introduced. It may be possible to interpolate in between (later study).

(3) All other criteria applies as appropriate.

(4) Mentioned that a null result would still be of use when used in conjunction with our AFGL accelerometer study.

2. Dr. Liu mentioned that the historical data base system (HDS) was inoperable, but he expected it should return any day.

3. Dr. Liu suggested that I work with Ms. Lori McCarter as previously planned. She would help me to get to know the system and develop programs which would retrieve my PPE data for use in the analysis.

30 Jun:

1. Ms. McCarter wrote a program (COMBINE) which would retrieve and merge my data set with the system flux file.

2. I continued to get familiar with the system.

3. Dr. Liu and Ms. McCarter suggested using available test cases to familiarize myself with TRACKS.

4. I went through the radar cross section (RCS) data to obtain test cases (see Attachment 1) appropriate to our study. These will be available to run on TRACKS when HDS is up.

01 Jul:

1. Ms. McCarter is having some difficulty in figuring out how to get the TRACKS program to input the new FLUX data set. She's still working on it.

2. HDS still down.

3. I learned how to construct input cards for the TRACKS system. For details see the TRACKS program report (Attachment 2).

4. Capt. Crockett provided me with a test case to input into the TRACKS program. The run was unsuccessful. Try tomorrow.

02 Jul:

1. I was informed by Dr. Wackernagel that the amount of data which would be required for the number of satellites I wanted and the amount of days I wanted would be unmanagable. Therefore, I narrowed the number of satellites down to 21 by eleminating the satellites whose probability would be low on getting high resolution also. In other words, I chose the payloads and eliminated the R/B and debris.

2. HDS is up. Gave Sgt. Pearsch (HDS) the satellite numbers of interest. She will have element sets and observations ready by next Monday. Ms. McCarter will work on getting those ready on the Gould system for our return to the Springs.

3. I ran the TRACKS program with subroutine HANDE successfully with the system flux. T.FLUX succesfully transformed my flux data to TRACKS format but TRACKS doesn't want to use it. It wants to use the system flux instead. That took me to 5:30 pm Thursday.

Recommendations:

Things to get accomplished before returning;

1. Make sure they have TRACKS receiving "our flux".

2. Make sure someone will be there to put the rest of our files on the Gould disk.

3. Coordinate with Dr. Liu on the future trip.

ATTCH 1

The following is a list of the satellites which were chosen for the study. Included is the satellite number, period, inclination, apogee, and perigee.

SAT NUM	PER (MIN)	INCL (DEG)	AP (KM)	PE (KM)
5281	104.3	74.0	1553	373
7003	106.1	74.0	1696	396
11285	98.4	74.0	878	485
14722	94.9	74.6	680	342
2389	126.8	81.4	3612	355
5580	105.4	82.1	1487	538
2150	133.9	82.4	4671	343
12848	108.5	82.5	1909	402
11161	95.1	82.9	552	359
14075	102.2	82.9	1421	302
7337	106.5	83.0	1601	394
12138	108.1	83.0	1870	403
12388	108.0	83.0	1878	393
3669	128.0	88.4	3493	576
3173	199.0	100.0	9240	588
3174	207.4	100.1	9894	561
3825	152.2	104.7	5656	475
STABLE PERIGEE ORBITS:				
8492	708.0	63.5	39717	154
15476	717.0	63.5	39871	482
8521	588.2	63.6	33658	96
8833	714.8	63.3	39871	333

ATTCH 2

TRACKS Program Report

TRACKS stands for Test, Research, and Analysis of Celestial Kinetics for Spacetrack. It is a highly versitile collection of programs with many functions.

To run the tests for this project requires that I construct input files for every satellite to be tested. These input files consist of orbital element sets and site observations. These files go into the differential correction program DCMOD whose end product is the RMS of the residuals of the predicted position.

The following is a summary of the steps in the initial in house testing process, and is intended as a guide when we return to finish the testing in the future. These steps use file cards as is necessary input format for the TRACKS system, and is the basic format that the HDS will have for our main tests.

The first step is to get into the special editor on the Gould computer system with the following entries: CTRL G, BEAT, BW, J.DFM. This series of steps gets us into the card editing mode. The commands commonly used are FLIST, DELE(card#,card#), MODI(col#,correction %), ADD(card#). The input

file consists of the following input cards: (all specific guidance contained in the TRACKS users manual)

1. Program Card: DCMOD. This is an applications program which performs a differential correction. It in turn requires two inputs: observations (obs) and element sets (elset). The observations come from the OBSFIL and the element set comes from the elset card.

2. Element Set Card: This card consists of the satellite number, international designator (not included), epoch time, basic coeficients (including the drag coefficient, satellite number, inclination, right ascention of the ascending node, eccentricity, argument of perigee, and epoch revolution.

3. SELOB Card: This is the observation retrieval function card. It selects observations from the OBSFIL for the tracks program as is the case for the in house data base test, or selects observations from the HDS data base for the more general tests which I will perform.

4. DCMOD P-card: This is the parameter control card. Specifically we are only concerned with the following columns: 7(epoch control set to "1"), 25-31(element correction control all "1"s), 62(ephemeris generation desired "26"), and 80(card type "P").

5. The last card is the end of file card (starting at column 1 "ENDOFJOB").

B. Running the TRACKS Program. This requires the following:

1. Simply type BTRKS.

2. It will come back and ask for an output file. Just name it OUT.

3. It will then ask for an input file. This is the file which contains the orbital elements of the selected satellite. The inhouse data base had the only available set. When we return we will obtain this file from the HDS data base as is put on the Gould.

4. Next the program asks for an OBSFIL. This will have to be from separate files created from the HDS data base for each satellite.

5. The program the runs a differntial correction and prediction. The prediction RMS of the residuals is what we are interested in. The ratio of the fitted to the observed RMS is an excellent indicator of the new parameters ability to improve prediction. It is this parameter which I will plot vs time, and also I will summarize with the average RMS with and without PPE .

C. Miscellaneous:

1. Volume Manager: Allows for transfer of files between accounts. For example: TSM> volmgr, > copy (carl)am8632 elset3.

2. T.FLUX: this is suppose to transform a given flux file to TRACKS format. This is not working according to the program directions, so we may have to go a different route. Lori is going to work on it. This was the biggest time waister of all.

END

DATE

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